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Sediment Classification and Bathymetry Data Acquired from the AN/UQN-4 Depth Sounder in Support of MTEDS

Technical Report under Contract N00039-91-C-0082,
TD No. 01A2049, Sensor and Environmental Support for MTEDS

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26 October 1995

Technical Report

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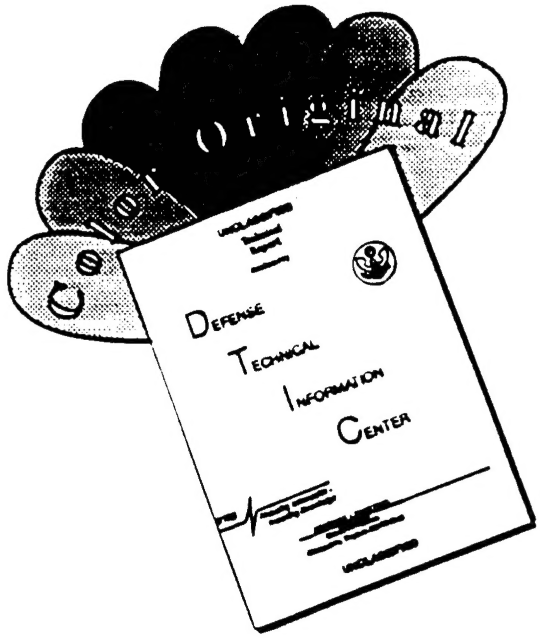

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A realtime system for the measurement of the bottom reflection coefficient using the AN/UQN-4 depth sounder was developed. Data provided by the system is transferred to the MTEDS database system where it is made available to the Acoustic Sediment Classification System (ASCS). In addition to the bottom reflection coefficient, the system also provides time and ship's position from a built-in GPS receiver, and depth data for the MTEDS database. Three sea tests provided data for system development. In addition, geophysical measurements, which were made during the sea tests by the Coastal Benthic Boundary Layer Special Research Project, were used to verify the system results. Basic design features of the system, both hardware and software, are discussed.

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1. INTRODUCTION

An important environmental parameter affecting the performance of a minehunting sonar and minehunting tactics is sediment type. This project studied the feasibility of using the ship's depth sounder to determine the bottom reflection coefficient, from which the bottom type can be inferred.[1] The AN/UQN-4 is the standard Navy depth sounder[2] used by all Navy vessels, including minehunters and sweepers. If it could be adapted for bottom typing in addition to depth sounding, a new and valuable capability could be added without developing a special purpose system requiring installation of additional transducers in the ship's hull.

A number of projects have been leveraged to provide the necessary capability at minimum cost, including the acoustic seafloor classification system (ASCS) under development at the Naval Research Laboratory, Stennis Space Center (NRL/SSC), and the hydrographic data recording system (HDRS) developed at ARL:UT under sponsorship of the Defense Mapping Agency (DMA). The former is a sediment classification system with mine burial prediction capability,[3] and the latter an automated data collection system designed to non-intrusively collect analog and digital depth information from the AN/UQN-4 and merge the data with ship's position as measured using a global positioning system (GPS) receiver.[4] Additional leverage was obtained from recent results of research[5] into bottom penetration and reflection acoustics at ARL:UT sponsored by NRL/SSC.

Data from several sea trials have been analyzed in support of the effort. The data consisted of acoustic bottom sounding data taken directly from a AN/UQN-4 system, a modified version of the HDRS which used the AN/UQN-4 transducer, and from a system designed specifically for the purpose of sediment typing. In addition to the acoustic data, sediment samples were acquired at the various sites visited. The parallel collection of geophysical and acoustic data allowed direct verification of the sediment typing. From recent research projects into bottom penetration and reflection, a theoretical basis for sediment classification from simple reflection loss measurement was developed.[6]

As a second objective, provision for depth logging has been implemented. The standard AN/UQN-4 has two forms of output: a paper chart recorder, and a 40-line parallel digital output used to drive the local and remote displays. The HDRS system provided a non-intrusive tap which allowed both the digital depth and analog waveforms from the transducer to be automatically recorded by a computer for each ping. Additionally, navigation and time information from a GPS receiver are logged along with the depth data. The sources of depth measurement error in the AN/UQN-4 were studied as part of the HDRS program. Additional hardware, including pitch and roll sensors, and software, including a bottom tracking algorithm, were added to the HDRS system to improve depth sounding accuracy. The AN/UQN-4 typically provides accuracy of 5-10% of the actual depth; the HDRS system accuracy is within 1-5%. Additional software for the HDRS was developed by the MCM Tactical Environmental Data Systems (MTEDS) to implement the sediment classification algorithm and output classification, depth, and position information in realtime.

In summary, a system was developed which logs geodesic position, water depth, and bottom reflection coefficient, and provides statistical measurements that, subject to further verification, are potentially suitable for input to the ASCS. The data is transferred through an interface computer and stored in the MTEDS database.

The following sections describe our efforts to ascertain the suitability of the AN/UQN-4, the data collection hardware, the data processing software, and the sea tests in which the system was tested and demonstrated.

2. SUITABILITY OF THE AN/UQN-4

Our approach has been to apply existing hardware on Navy ships as much as possible. Initially, there was justifiable concern that the AN/UQN-4 transducer may not be compatible with the ASCS. Through a rigorous analysis of bottom echo characteristics[7] supported by field tests, it was demonstrated that the AN/UQN-4 transducer is capable of supporting the algorithms in the ASCS with minimal reduction in performance. This was demonstrated[8] during the Eckernförde sea test in which an AN/UQN-4 transducer and the narrower beam ASCS transducer were operated over a variety of sediment types, including hard till and soft mud with gas pockets.

Part of the bottom classification algorithm relies on using broadband transmit signals to provide information about the bottom reflection coefficient over a broad spectrum. The AN/UQN-4 transmitter operates at a single frequency, 12 kHz, and the system has a bandwidth of 2 kHz. The transducer is usable over a bandwidth of at least 8 kHz around 12 kHz. During the Key West sea test the HDRS transmitted a linear FM sweep from 8 to 16 kHz, which provided wider bandwidth than normally available with the UQN-4's standard electronics.

The AN/UQN-4 depth sounder is an old system (over 30 years in service), and many parts are obsolete and can no longer be obtained by the maintenance depot (NWSC CRANE). ARL:UT is currently tasked, along with NWSC CRANE, to provide input on the Navy's requirements for an upgrade to the AN/UQN-4's electronics to EDO Corporation. This program is just getting underway, and ARL:UT is expected to have the opportunity to address special requirements such as those of MTEDS in our input to EDO. ARL:UT has proposed a redesign to NAVSEA which includes all of the features currently in place in the HDRS as modified for MTEDS.

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3. HARDWARE

A parallel project, the hydrographic data recording system (HDRS) sponsored by Defense Mapping Agency (DMA), was tasked to design an automated data collection system using the AN/UQN-4 and a GPS receiver.[4] The HDRS program developed four prototypes, beginning with the phase 1 and 2 Macintosh-based systems. These early prototypes measured both the AN/UQN-4 digital depth output and the analog waveforms. The analog waveform capture capability was not designed into the phase 3 and 4 prototypes because DMA's primary concern at that time was minimizing the size and cost of the final HDRS unit.

Development of the HDRS was begun independently of the MTEDS bottom classification system. However, early on in the design of both systems, it was realized that because both were intimately involved with the AN/UQN-4 (especially the transducer) a cooperative effort would be advantageous to both projects. After the sea test of the phase 3 "suitcase" HDRS, it was set aside by the HDRS project to do final development of an even smaller and more portable phase 4 HDRS. Although the phase 3 HDRS did not have analog waveform capability originally, it had open slots and processing capability which could be used to implement functions needed for MTEDS. It also provided MTEDS with a data collection system that is more portable and rugged than the original Macintosh-based system.

As part of MTEDS, the phase 3 HDRS was modified to support analog waveform capture from the transducer. A digital signal processing (DSP) card was purchased from National Instruments which provided two channels of analog input and an AT&T DSP coprocessor. The DSP was tasked with sampling both the transmit and receive waveforms from the non-intrusive tap. The DSP also calculated new waveforms which could be transmitted using the Instruments, Inc., L2 power amplifier added to the system for MTEDS. Algorithms from the previous MTEDS data acquisition system, to find the bottom from analog receive signals, were added to the HDRS, and new algorithms for inverse filtering and phase aligning the result were implemented as well.

These modifications in turn have proven to be useful to the HDRS project. Following post-sea trip laboratory analysis of the recorded data, algorithms were developed which produce more accurate and reliable depth data than that provided by the standard AN/UQN-4 system. Digital signal processing techniques along with better transmit waveforms reduced errors in depth estimates from 5-10% of the depth (when the system is properly adjusted) to 1-5%. The standard AN/UQN-4 system requires constant attention by an operator to keep it adjusted for varying depths and conditions. The HDRS operates reliably under a wide variety of depths and conditions with little or no adjustments. In addition, the HDRS project uses small, portable, self-contained, and ruggedized hardware which reduces the resource demands (both personnel and facilities) on sea trips.

After determining that the AN/UQN-4 transducer had the necessary beamwidth and bandwidth to support bottom classification, a data collection unit was constructed to capture the analog signals from the AN/UQN-4 for MTEDS. The initial design was based on the prevailing HDRS prototype. At the time, HDRS was between phase 1 and phase 2 prototypes, which were built around a Macintosh computer, and capable of recording analog waveforms in addition to bathymetry. The hardware and software from that prototype performed many of the functions required by MTEDS, which enabled MTEDS researchers to leverage the DMA sponsored effort and rapidly field a working system to begin collecting data. A sea test off Panama City, Florida, provided an opportunity to collect bottom reflection data over sandy sediments.

Shortly after the Panama City tests, the HDRS program completed construction of a ruggedized, portable "suitcase" prototype built on a passive backplane PC platform. This system featured a built-in GPS receiver and uninterruptable power supply (UPS) and a flat-panel display. This phase 3 HDRS prototype was taken aboard USS GLADIATOR (MCM 11) in March 1994 and tested as part of the HDRS project. It captured the analog waveforms and digital depth but had no capability for bottom classification or transmitting broadband waveforms.

Finally, the phase 3 HDRS prototype, in conjunction with MTEDS developed software, was used in the Key West sea test to demonstrate

bathymetric and sediment classification data collection and transfer to the MTEDS database.

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4. DATA ACQUISITION SYSTEM

4.1 AN/UQN-4

The following is a brief description of some of the features of the AN/UQN-4 depth sounder that are relevant to this project. The AN/UQN-4 is a standard U.S. Navy depth sounder found on most U.S. Navy ships. There are two principal units associated with it: the electronics unit and the transducer. The transducer is mounted on or beneath the hull. The transducer cable, which must penetrate the hull, is connected to the electronics unit. The beamwidth of the transducer is 37° at 12 kHz. The system beamwidth, obtained from a combination of projector and receiver beam patterns, is 26°. There are two displays for the depth reading associated with the electronics unit: a digital front panel display and a chart recorder. A front panel switch allows the operator to select a depth range: 600 ft, 600 fathoms, or 6000 fathoms. Changing the depth range changes the transmit pulse duration and the interval between pulses. The duration is varied from 0.33 to 20 ms depending on which range is selected. All pulses are 12 kHz continuous wave signals. A second display unit, which might be located near a minehunting sonar's console, for example, is connected to the electronics unit by cable.

4.1.1 Non-Intrusive Tap

A passive interface with the AN/UQN-4 was fabricated. A diagram of the data acquisition system including the interface is shown in Fig. 4.1. The interface intercepts signals at two points in the system. The transducer cable, which normally plugs directly into the electronics, is plugged into the interface. The signals normally present on this cable are routed through the interface and back out to a cable which is connected to the electronics unit. Similarly, a second set of signals is taken from the cable which connects the electronics unit with the auxiliary display unit. The use of this interface does not affect the normal operation of the AN/UQN-4; however, it does provide the capability for using the transducer independently of the standard AN/UQN-4 electronics.

There are two signals present on the transducer cable: the transmit pulse and the receive pulse. A transmit/receive (TR) switch was installed in the

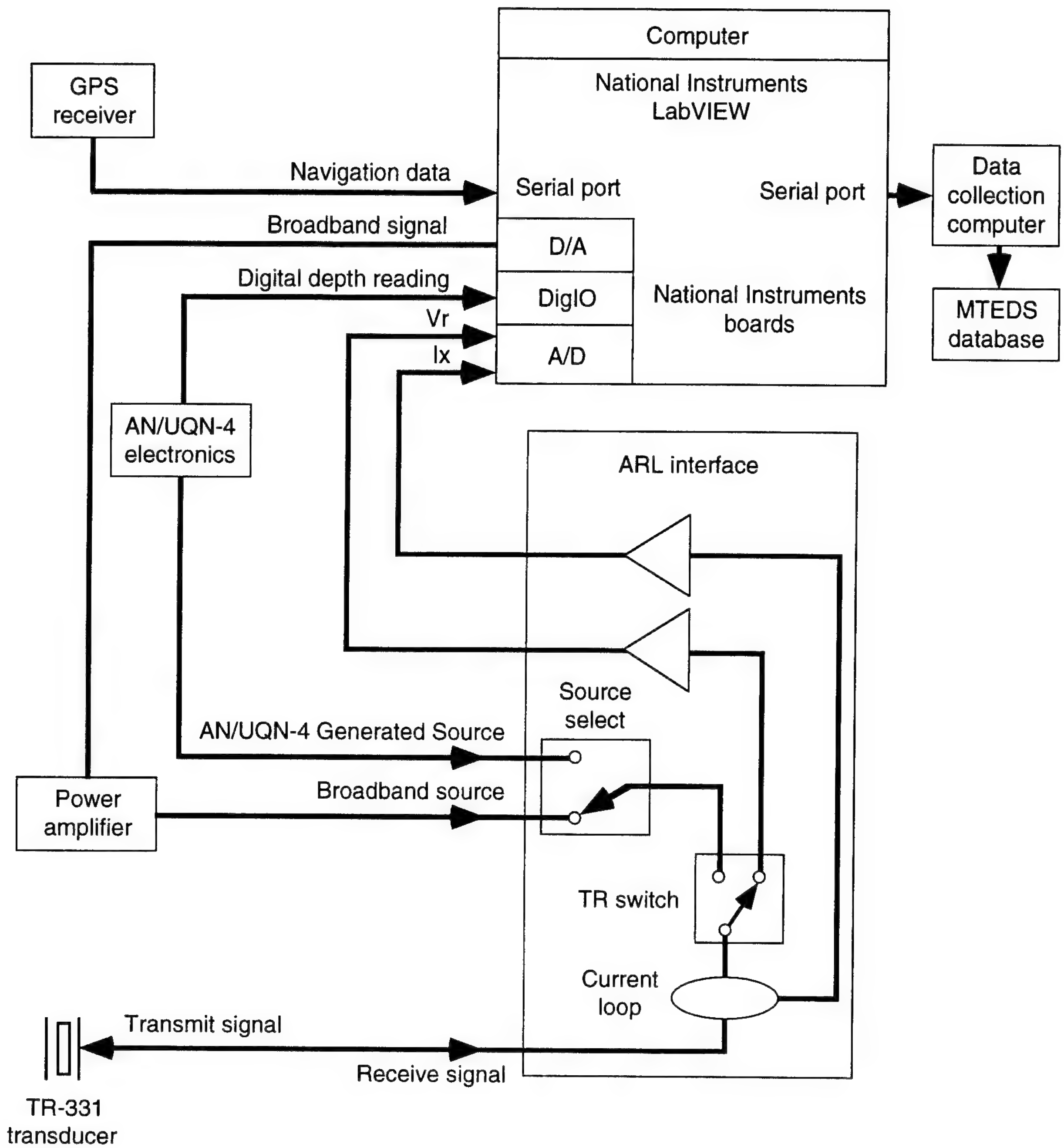

Figure 4.1
MTEDS AN/UQN-4 data acquisition system.

interface and connected to the transducer cable. The TR switch passes the low level receive signal through the receive circuitry but blocks the high level transmit signal, thus protecting sensitive components. The receive signal is amplified, filtered, and then passed on to the analog to digital (A/D) converter, which is located in the computer. In addition to the TR switch, a current loop has been installed to measure the transmit current. The signal produced by the current loop is connected to a second A/D converter. The A/D converter samples the signals at regular time intervals and generates a discrete value for the input voltages at each time interval. The sample rate for the A/D process, based upon the signal bandwidth, was 52 kHz for the AN/UQN-4. Both signals are then available for processing and recording by the computer. The computer and interface units were leveraged from the DMA sponsored HDRS project, described in the previous section.

The auxiliary unit has a 4-digit nixie tube display for depth. A set of 40 lines drive the four nixie tubes (four decimal digits), ten lines per tube. These signals, which are present on the auxiliary display unit cable in the interface, are connected to a digital input device in the computer which logs the AN/UQN-4 depth estimates.

4.2 EXTERNAL ELECTRONICS

As mentioned above, the interface provides the capability to use the AN/UQN-4 transducer independently of the AN/UQN-4 electronics. When operated in this mode, depth estimates are not available from the AN/UQN-4 and must be provided by the HDRS system. One advantage of using the system in this second mode is that custom pulse types can be used and, in particular, broadband pulses.

A desired pulse replica can be generated by the computer and converted to an analog signal by the D/A converter. This analog signal is then input to a power amplifier which drives the transducer during the transmit phase of the ping cycle. When the system is used in this mode, only the transducer unit of the AN/UQN-4 is used and the HDRS system functions as a stand-alone depth sounder.

4.3 MTEDS DATA LINK

Results from the bottom sounder system are forwarded to the MTEDS database computer over a serial port. The depth, navigation information, and time are transmitted at periodic intervals. The reflection coefficient is transmitted when available. Its computation, discussed below, requires multiple pings and is forwarded upon completion. Details of the bottom sounder message are described in Appendix A.

4.4 SYSTEM COMPUTER

Two different system computers have been used. An Apple Macintosh was used for the original system. Later, the phase 3 HDRS, which is designed around an IBM compatible PC, was used. Both types of computers were programmed in the National Instruments LabVIEW graphical programming language. For the most part, little difficulty was encountered when porting the program from one computer to the other. National Instrument data acquisition boards were used with both computers, the appropriate boards for each type of computer, to perform the various control, data input, and data output tasks. Control drivers were supplied with the boards. They are accessed directly through the LabVIEW program, and therefore no low-level, time consuming programming effort was required. The LabVIEW programs were also able to provide access to the serial port link used to communicate with the database computer.

A few different types of storage media were used for data storage: 8 mm magnetic tape, removable hard drive disks, and optical disks. Again, these devices were accessed through LabVIEW, although some low-level programming effort and additional software drivers were required.

Navigation and time of day data from a GPS receiver were supplied to the computer through a serial port. The LabVIEW system was used to read and process the data packets from the GPS receiver.

5. DATA PROCESSING

5.1 CALIBRATION

System calibration is needed for calculating the bottom reflection coefficient. However, no laboratory calibration was available for any of the data sets analyzed for this project. An estimate of the system calibration was performed by analyzing data gathered during the sea trials. In all data sets taken at sea, at least one data set was taken under calm sea conditions. The high signal-to-noise ratio of the data provided a good second bottom echo: Figure 5.1 shows an example of such a return. The calm water-air interface acted as a near-perfect reflector that could be used for calibration purposes. Under these conditions and assuming that all loss in signal strength can be accounted for by radial spreading, absorption, and bottom loss, it was possible to perform the self-calibration of the sonar's system as follows. Given the echo levels of the first and second bounce (EL_1 and EL_2), the bottom loss (BL) may be expressed as

$$BL = (EL_1 + 20\log(2d) + 2\alpha d) - (EL_2 + 20\log(4d) + 4\alpha d) \quad , \tag{5.1}$$

where

EL_1 is the echo level of the first return,
EL_2 is the echo level of the second return,
d is the water depth, and
α is the attenuation of sound by water.

Let us define a system calibration M such that

$$BL = (EL1 + 20\log(2d) + 2\alpha d) + M \quad . \tag{5.2}$$

Substituting from the above, it is obvious that

$$M = -(EL2 + 20\log(4d) + 4\alpha d) \quad . \tag{5.3}$$

We assume here that the source level (SL) remains constant. Variations in SL are measured with the current loop. For varying SL, M is given by

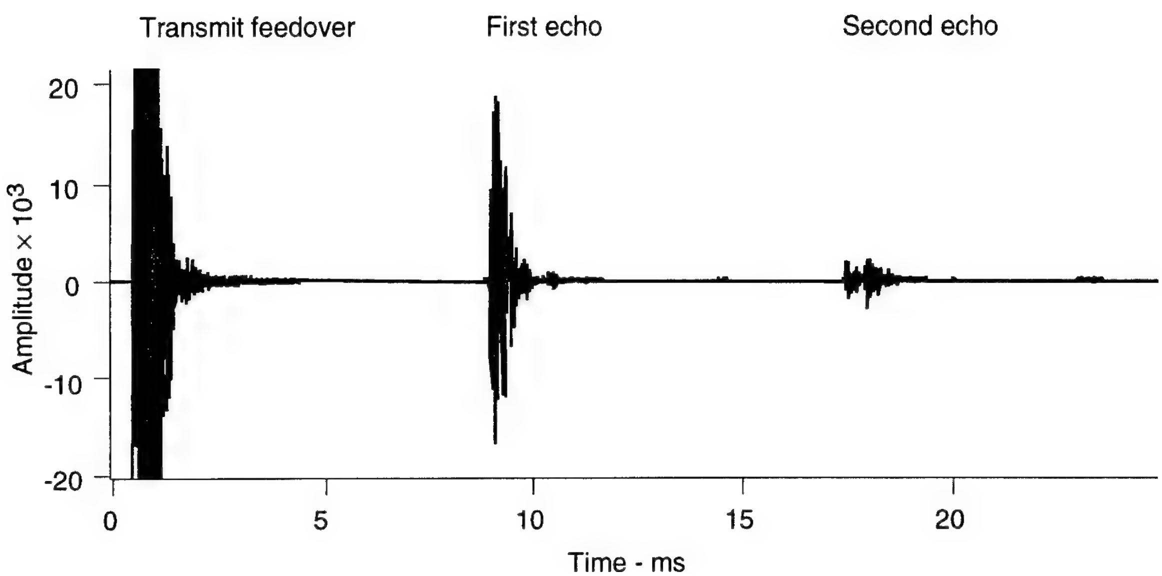

Figure 5.1
Example of depth sounder return.

$$M = -(EL2 + 20\log(4d) + 4\alpha d) - SL + SL_o \quad , \tag{5.4}$$

where SL_o is the source level, EL2 the second echo level, and d the depth, used in the calibration data set.

5.2 WIENER FILTER

A Wiener filter was designed for deconvolving the bottom returns. Output from the filter allows the spatial resolution of the bottom echoes to be optimized. The filter was designed as follows. If h is the echo-sounder system impulse response, then the system output y, due to an input impulse signal x, is given by computing the convolution of h with x:

$$y = h \otimes x \quad . \tag{5.5}$$

If possible, we would like to find the inverse transfer function (inverse filter), h^{-1}, such that

$$x = h^{-1} \otimes y \quad . \tag{5.6}$$

To find h^{-1}, we observe that the convolution operation above can be performed by taking the product of the Fourier transform **F** of h and x, and finding the inverse Fourier transform:

$$y = \mathbf{F}^{-1}[\, \mathbf{F}(h) \;\; \mathbf{F}(x) \,] \quad . \tag{5.7}$$

Thus by using the Fourier transform, an inverse filter can be designed as follows:

$$h^{-1} = \mathbf{F}^{-1}[\, \mathbf{F}(x) \,/\, \mathbf{F}(y) \,] \quad . \tag{5.8}$$

In practice, the infinite bandwidth required to produce a true impulse is not available with the AN/UQN-4. The usable bandwidth of the AN/UQN-4 transducer is about 10 kHz, and the signal x is restricted to this bandwidth. To reject the out-of-band noise, the inverse filter is modified into a Wiener filter, which may be expressed as

$$h^{-1} = \mathbf{F}^{-1}[\ \mathbf{F}(x)\ \mathbf{F}^{*}(y) / (\ \mathbf{F}(y)\mathbf{F}^{*}(y) + e)\ ] \quad , \tag{5.9}$$

where e is the estimated background noise spectrum level in the received signal, y.

For the purposes of constructing a filter, measuring the ideal shape of the received signal y can be accomplished by transmitting a pulse and receiving an echo from a perfect reflector. The air-water surface makes a good reflector, but since the transducers were mounted on the hull and pointing downward, this was not an option. As an approximation, echoes from areas with an acoustically "hard" bottom were used. Figure 5.2 shows the effects of the filter on a bottom return from a hard bottom. As can be observed, a good approximation of a band-limited impulse was achieved.

5.3 BOTTOM TRACKER

The sediment classification models are based on the reflection coefficient which is derived from the coherent component of the bottom returns. There is considerable variation in the ping-to-ping amplitude and phase of the returns due to scattering from bottom surface roughness and volume inhomogeneities. The variations in the phase are due to local depth change as the sonar moves. As discussed above, Chotiros[7] shows that for a sonar with parameters consistent with the AN/UQN-4, the scattering component is random and the bottom reflection statistics can be computed from an ensemble of several pings. In order to do so, it is first necessary to align them.

A tracker was designed to follow the time delay of the pulses from the water-sediment interface on a ping-to-ping basis. This information is then used to align the pulses. Once aligned, the pulses can then be summed coherently. If all the reflected energy comes from the water-sediment interface, the filtered return will resemble the impulse function described above. If there is penetration by the acoustic pulse into the sediment and additional reflection or scattering from beneath the interface, then the return will be more complex. Most returns, even the complex ones, have a well defined leading edge associated with the interface. The tracker looks for and works with this leading edge. It also

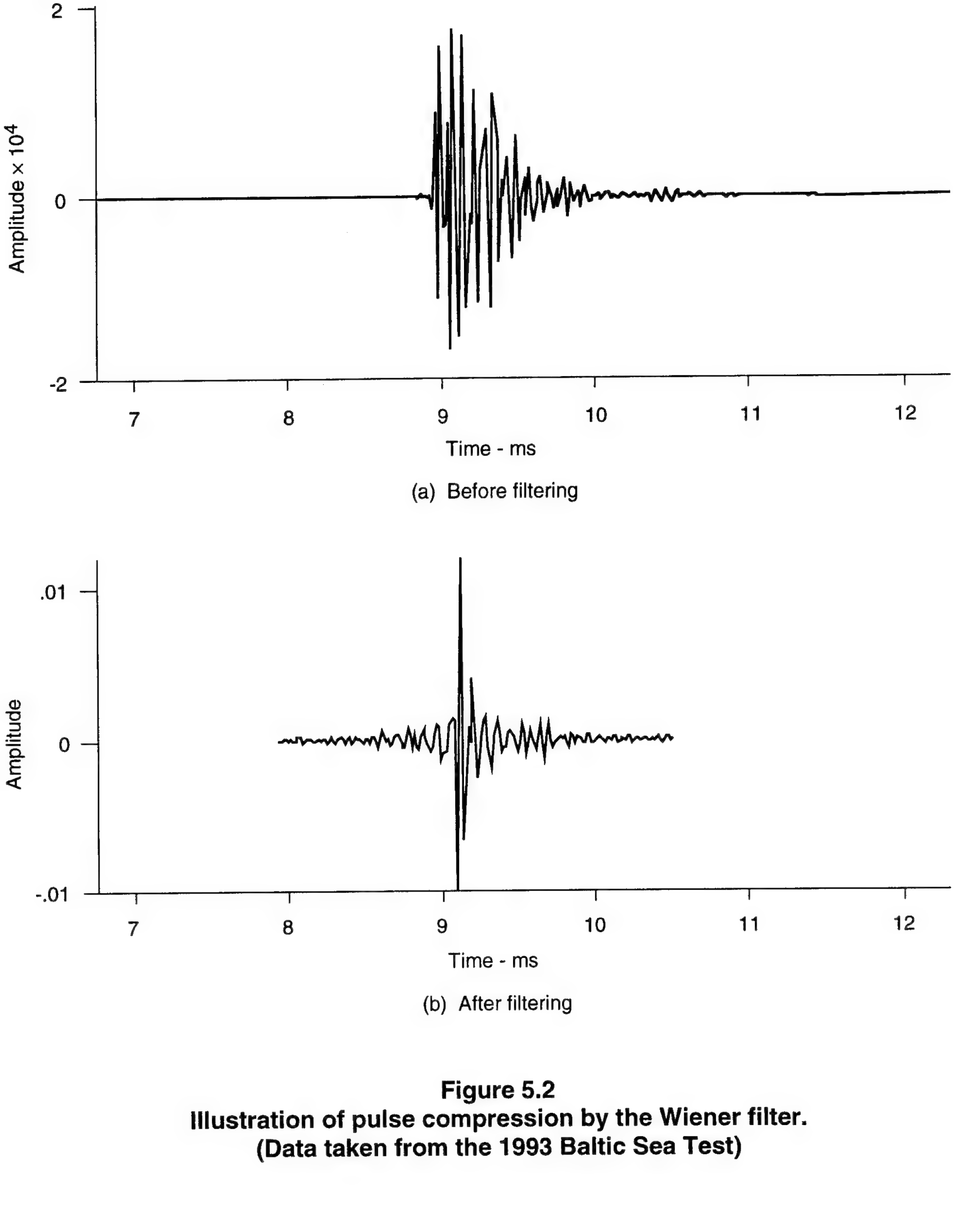

Figure 5.2
Illustration of pulse compression by the Wiener filter.
(Data taken from the 1993 Baltic Sea Test)

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assumes that the phase change between pings is small and that only the leading edge of the return contains the reflection from the water-sediment interface. This assumption reduces the computational load of the tracking and alignment process and reduces its susceptibility to error caused by noise. The required alignment is estimated by locating the peak in the crosscorrelation function between a replica, constructed from a running average of previous returns, and the windowed section of the return from the current ping. The latter is then shifted by the indicated time interval and added to the moving average. By using a moving average replica, the tracker can adapt to gradual changes in the character of the response of the sediment-water interface. Once started, the tracker runs continuously. Figure 5.3 is a flow diagram of the calculation software.

5.4 BOTTOM REFLECTION COEFFICIENT

The bottom reflection is computed from a series of sequential returns; the number to average is preset by the system operator, typically 100. Once the reflection coefficient has been computed, statistics from a series of time intervals are computed. In order to minimize data storage requirements of the database computer without loss of information, a statistical analysis of the reflection coefficient is performed. The coefficient samples are grouped into sequential time intervals consisting of one or more samples. Statistical results for each interval include mean, standard deviation, minimum, and maximum values. These data are then forwarded to the database computer. Subject to further verification, the data is potentially compatible with the acoustic sediment classification system (ASCS). Included in the data message sent to the database computer are the results of time and position measurements performed just before and after the ping sequence is taken. Details of the depth sounder message can be found in Appendix A.

In addition to the ASCS, which provides detailed sediment classification as a function of depth, the AN/UQN-4 data acquisition system also provides a simple measurement of bottom reflection loss, which can be used as an initial bottom classifier. Based on research work on bottom penetration acoustics at ARL:UT, supported by NRL/SSC, a reliable model of acoustic bottom loss has been developed which allows simple bottom classifications to be made.

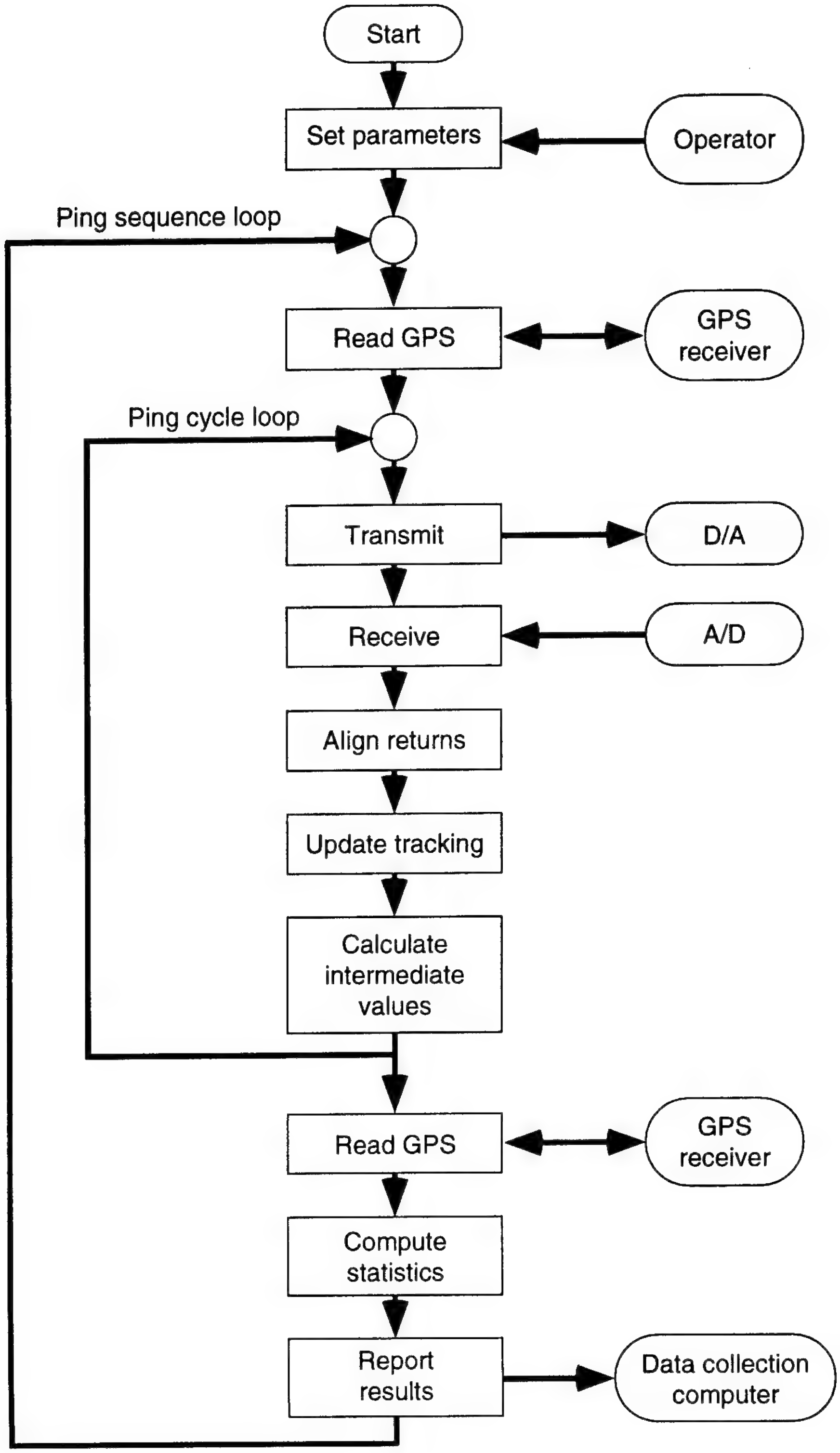

Figure 5.3
Control program flow.

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5.5 BATHYMETRY

MTEDS adapted the original HDRS software to run concurrently with the MTEDS software. The current MTEDS/HDRS software system controls the entire system for both projects. Depth, position, and time are measured by the HDRS subsystem, and the bottom reflection coefficient, by the MTEDS subsystem. Raw data and results from both systems are made available to other systems over a serial port or stored off line through a SCSI port for laboratory analysis. As a result of this dual capability, data gathered on sea tests have been shared between the projects, thus greatly expanding their experimental databases. Details of the HDRS bathymetry data collection function may be found in Ref. 4.

As part of the sea test preparations, a small area in the vicinity of the ARL:UT Lake Travis Test Station was surveyed and processed into a bathymetric map. The result is shown in Fig. 5.4, in the form of a three-dimensional relief map, constructed on a Silicon Graphics workstation.

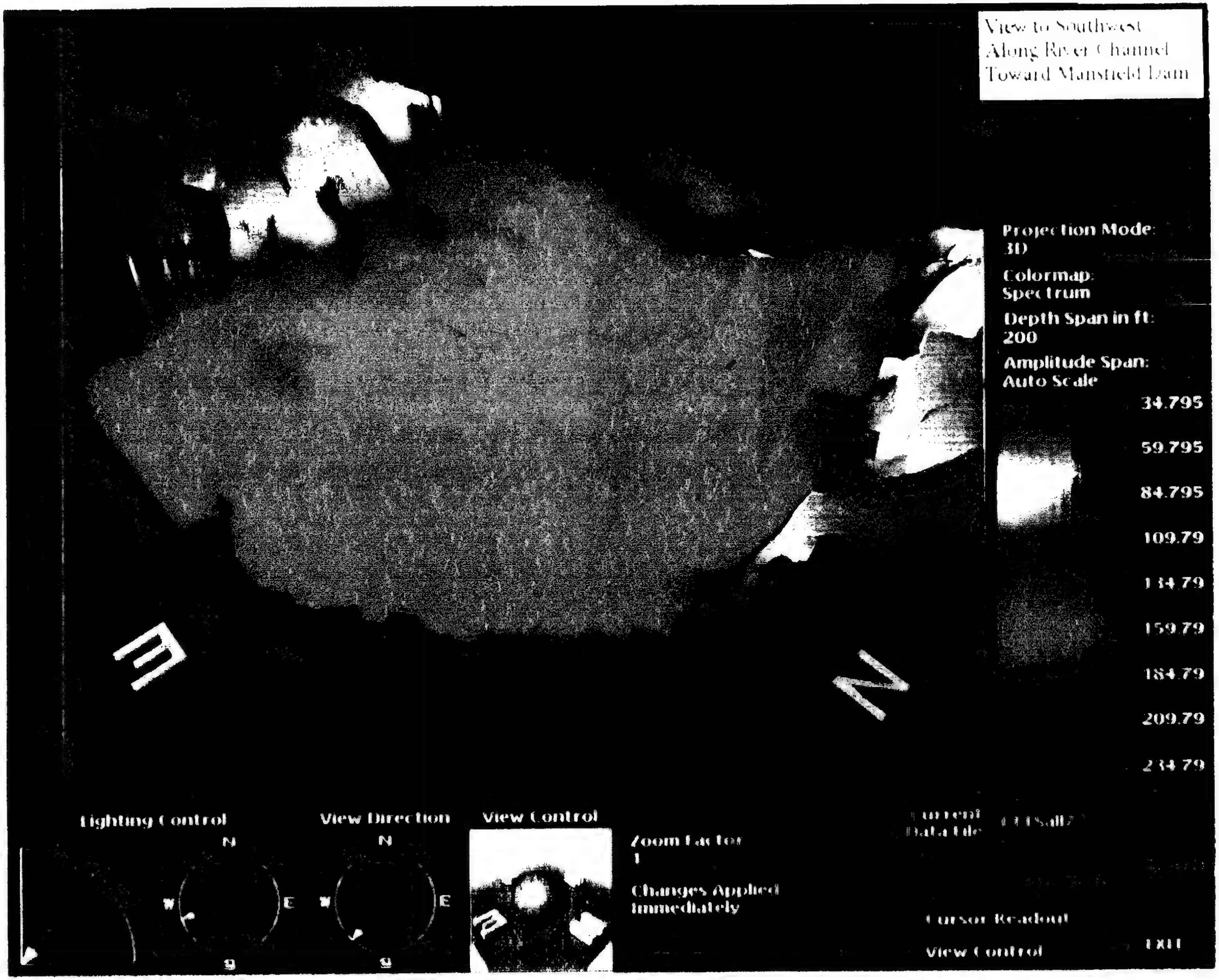

Figure 5.4
Bathymetric map of the area around the ARL:UT
Lake Travis Test Station.

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6. SEA TESTS

Data were collected in three sea tests at three different sites to verify that the AN/UQN-4 transducer is suitable for sediment classification, for testing the sediment classification function, and testing the data link to the MTEDS database. In each case, ground truth was provided by the coastal benthic boundary layer (CBBL) research program, in the form of core samples.

6.1 ECKERNFÖRDE BAY, GERMANY

The MTEDS/CBBL sea test in the Eckernförde Bay of the Baltic Sea near Kiel, Germany (1993), provided the first data set. The bottom is a gaseous mud overlying glacial till.

The NRL ASCS sediment classification system was in operation during this sea test, using both a narrowbeam transducer and TR-192B transducer. Bottom returns were recorded for analysis. A copy of sections of these data were made available to ARL:UT and have been subjected to the analysis described above. Geophysical data in areas associated with the data were also acquired under the CBBL research program. Measured bottom reflection losses were in excess of 20 dB over the soft muddy sediment, and approximately 8 dB over the hard till.

6.2 PANAMA CITY, FLORIDA

A sea test was conducted on the RV GYRE near the Florida coast during August 1993 as a joint project between MTEDS and the CBBL. Panama City, Florida, which is 30 miles northwest of the test area, was base for the operation. The transducer was a model TR109, from Raytheon.

The bottom is terrigenous quartz sand with biogenic carbonate material. RV GYRE remained anchored on station at a number of sites (listed in Appendix B). While on station, the bottom sounder was operated and returns stored. Although the ship was anchored, there was still enough ship motion between pings (even when the seas were calm) to obtain random variations in the returned echo, thus allowing the statistical processing to be applied to compute

the coherent and incoherent components of the bottom return. Bottom samples obtained under the CBBL program provided ground truth for comparison with the outcome of the acoustic data analysis. Analysis and interface programs were still under development at this time, and a link to the MTEDS database computer was not yet available. Measured bottom reflection loss values were in the region of 11 dB over the sandy sediments.

6.3 KEY WEST, FLORIDA

The final sea test was conducted on RV SEWARD JOHNSON, using a TR323B transducer, in the Dry Tortugas during February 1995. The Dry Tortugas are located in the Florida Keys, and Key West was used as the base of operations.

The bottom is carbonate mud and biogenic carbonate detritus (hermitific corals, shells, etc.). The data acquisition strategy used at Panama City was used here. Appendix C contains a list of the sites at which bottom sounder data were acquired along with physical bottom samples. In addition, a television camera mounted on a remotely operated vehicle allowed visual recording of the bottom at the sites.

The bottom reflection coefficient and depth estimates were computed in realtime during the sea test. These results, along with navigation data, were forwarded over the link and successfully entered into the MTEDS database. In addition, the bottom returns were recorded for further analysis. Measured bottom reflection loss values ranged between 7 and 12 dB. These measurements were made over nine sites with varying degrees of hardness. Further crosscorrelation between reflection loss and sediment analysis results will further improve bottom classification capability.

7. ACCOMPLISHMENTS

A system has been developed whose primary purpose is to assist MTEDS with bottom classification. A system with the following capabilities has been developed to accomplish this goal.

- Recording of AN/UQN-4 digital depth and analog waveform data by a non-intrusive tap.
- Independent output of broadband waveforms using the AN/UQN-4 transducer.
- Measurement of the bottom reflection coefficient using the analog waveform data.
- Estimation of bottom depth with improved accuracy over the standard AN/UQN-4.
- Acquisition of time and position data from a GPS receiver developed under the HDRS project.
- Logging of raw receive and transmit waveforms, depth, and time and position data.
- Logging of bottom reflection statistics that, subject to verification, are potentially suitable for input to the ASCS for bottom classification and mine burial prediction.
- Transfer of logged data to the MTEDS data collection computer.

The application of the standard Navy echo sounder, the AN/UQN-4, for the purposes of logging bathymetric data, collecting data for sediment classification, and transfer of data in realtime into the MTEDS database has been successfully demonstrated. Work is underway to transition the above achievements into the mine warfare decision aids library (MEDAL), a tactical planning aid for the MCM Fleet.

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APPENDIX A
BOTTOM SOUNDER MESSAGE

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1. **Time/Position/Depth Packet (TPD)**

Line	Units/Explanation	Data Field
1. 0	DCM identifier:	1 char.
[TAB]	separator:	1 char.
mm/dd/yy	date:	8 chars.
[TAB]	separator:	1 char.
hh:mm:ss	time: 24 hr format	8 chars.
[TAB]	separator:	1 char.
dd° mm' ss.s" X	latitude: X = N/S	15 chars.
[TAB]	separator:	1 char.
dd° mm' ss.s" Y	longitude: Y = E/W	15 chars.
[TAB]	separator:	1 char.
X	sonar fault: 0 = no fault, 1 = fault	1 char.
[TAB]	separator:	1 char.
DDDDD	depth: (feet)	1-5 chars. Variable
<CR> <LF>	Carrage return/Line feed	1 or 2 chars.
2. EOT (0x04h; ^D)	end of packet:	1 char.

Total # Bytes = 57 - 62 bytes (including CR/LF,EOT)

2. **Echo Sounder Packet Format (UQN-4)**

Line	Units/Explanation	Data Field	
1.	2	DCM Identifier	1 char.
2.	RAW_UQN4_STATISTICS_V1.0A¬	Packet Title	25 char.
3.	FIRST_GPSDATEΔXXXXX¬	Day of year	19 char.
4.	FIRST_GPSTIMEΔXXX.XXXXXXX¬	Seconds	25 char.
5.	FIRST_GPSLATΔXXX.XXXXXXX¬	Degrees	24 char.
6.	FIRST_GPSLONGΔXXX.XXXXXXX¬	Degrees	25 char.
7.	LAST_GPSTIMEΔXXXXX¬	Seconds	18 char.
8.	LAST_GPSLATΔXXX.XXXXXXX¬	Degrees	23 char.
9.	LAST_GPSLONGΔXXXX.XXXXXXX¬	Degrees	24 char.
10.	NUMBER_OF_PINGSΔXXX¬		19 char.
11.	REFLECTION_LOSS(DB)ΔXXXX.XX¬	dB	27 char.
12.	START_TIME_MEANΔXXX.XXXXXXX¬	Seconds	27 char.
13.	START_TIME_SDΔXXX.XXXXXXX¬	Seconds	25 char.
14.	TIME_STEPΔXXX.XXXXXXX	Seconds	21 char.
15	ECHO_DELAYΔXXX.XXXXXXX¬	Seconds	22 char.
16.	NUMBER_OF_TIME_STEPSΔXXXX¬	Seconds	25 char.
17.	NUMBER_OF_STATISTICSΔXX¬		23 char.
18.	NUMBER_OF_BYTES_OF_DATAΔXXXXX¬	29 char.	
19 to 19+M	±X.XXXXE±XΔ ±X.XXXXE±XΔ . . . ¬	Statistics	M (varies)
20+M.	EOT (0x04h; ^D)	End of Transmission	1 char.

Note: Δ is a space, ¬ is a CR/LF

Line 19 contains the raw statistics data. The size field is M where:

M = NUMBER_OF_TIME_STEPS x NUMBER_OF_STATISTICS
x (10 + 'space char.')+CR/LF.

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APPENDIX B

PANAMA CITY SITE LOCATIONS
WITH BRIEF DESCRIPTIONS

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Sample id	Type	Date	Time (min)	Latitude N	Longitude W	Comments
0576-PC-LGC	URI gravity corer	29 Aug	1309	29 40.71	85 40.84	36 cm, coarse-med snd w/ many sm shell fragments
0577-PC-LGC	URI gravity corer	29 Aug	1402	29 40.95	85 40.29	47 cm, coarse snd w/ many shell fragments
0581-PC-LGC	URI gravity corer	29 Aug	1818	29 41.12	85 40.43	24 cm, coarse-med snd w/ shell fragments
0584-PC-LGC	URI gravity corer	30 Aug	1018	29 41.57	85 41.17	19 cm, med-coarse snd, some sm shell fragments; very thin layer of fine snd on top
0587-PC-LGC	URI gravity corer	30 Aug	1139			Loran coord suspect, stormy bridge GPS better; 31.5 cm; 0-9 cm c-med snd, 9-31 cm finer, m-fine snd
0588-PC-LGC	URI gravity corer	30 Aug	1311	29 40.74	85 40.41	Need to be checked with bridge no recovery, cc med snd, no shells
0589-PC-LGC	URI gravity corer	30 Aug	1401	29 40.77	85 40.48	Loran seems to be better; no recovery, cc gray well-graded med snd
0590-PC-LGC	URI gravity corer	30 Aug	1449	29 41.06	85 40.81	25 cm; coarse snd w/ lots of shell fragments, some whole shells
0592-PC-LGC	URI gravity corer	30 Aug	1654	29 41.03	85 40.49	10 cm; coarse snd w/ shell fragments
0596-PC-LGC	URI gravity corer	30 Aug	2004	29 41.03	85 40.50	20 cm; coarse shelly fragments, duplicate core
0597-PC-LGC	URI gravity corer	30 Aug	2117	29 42.11	85 40.50	37.5 cm; coarse shelly snd, some finer mat near bottom 4-6 cm
0598-PC-DC	diver cores	30 Aug				2 bubble cores, 2 for permeability and 1 water sample

Sample id	Type	Date	Time (min)	Latitude N	Longitude W	Comments
0599-PC-DC	diver cores	31 Aug	0830	29 40.71	85 40.42	2 cores; 4 gas cores
0608-PC-LGC	URI gravity corer	31 Aug	1950	29 41.47	85 40.92	sample washed out, coarse snd w/ shell fragments
0612-PC-DC	diver cores & photos	31 Aug	~1200			cleared 2.7 x 2.7 m area of shells directly under the VIMS tower
0616-PC-VC	GERG virbro corer	2 Sep	0715	29 43.95	85 42.17	0.9 m fine snd and mud on hard bottom
0617-PC-VC	GERG virbro corer	2 Sep	0826	29 41.61	85 40.90	25 cm coarse snd
0618-PC-VC	GERG virbro corer	2 Sep	0920	29 41.31	85 40.73	64 cm coarse snd
0636-PC-VC	GERG virbro corer	3 Sep	0731	29 40.81	85 40.38	1 bag coarse snd

APPENDIX C

KEY WEST EXPERIMENT SITE LOCATIONS INCLUDING DESCRIPTIONS

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Site	Lat (deg)	Lat (min)	Long (deg)	Long (min)	Depth (ft)	Comments
1	24	34.3326	82	51.4672	90	hard site, NZ penetrometer reads 700 kPa bearing strength
2	24	34.5000	82	51.0000	85	hard
3	24	35.0180	82	51.4770	87	medium, NZ penetrometer bearing strength increases from surface to peak at 7 cm of 650 kPa
4	24	35.9480	82	51.0970	86	medium, gas and core sample
5	24	35.5240	82	51.5170	89	medium, current meter site, NZ penetrometer peak at 15 cm of 300 kPa
6	24	36.5000	82	51.5240	81	soft site, core and gas sample
7	24	36.5950	82	50.5300	-	soft, east of APL/UW tower, no dives because of strong bottom currents
8	24	36.3530	82	51.2060	-	soft, southwest of VIMS, no dives because of strong bottom currents
9	24	34.5190	82	51.1320	-	reef, grab bag sample
	24	36.7000	82	50.7700		APL/UW tower
		36.5100		50.9400		VIMS

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26 October 1995

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